INDOOR AIR QUALITY ASSESSMENT

German International School
54 Essex Street
Cambridge, MA

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response Indoor Air Quality Program
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Background/Introduction

At the request of Jessica Reynold, Administrative Associate**,** the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the German International School (GIS), 54 Essex Street, Cambridge, Massachusetts. The assessment was prompted by occupant complaints of reoccurring upper respiratory problems over the past several years as well as temperature complaints.

On June 22, 2005, Mike Feeney, Director, and Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment at the GIS. The GIS occupies the third and fourth floors of a four-story, red brick building owned by the Archdiocese of Boston that was constructed in the late 1800s. Windows are openable throughout the building.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particulate matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The GIS houses a kindergarten through fifth grade student population of approximately 70 and a staff of approximately 20. Tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all but one area (Table 1), indicating adequate air exchange. However, it should be noted that all areas surveyed were unoccupied or had windows open, which likely explains reduced carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows closed.

The GIS has no mechanical ventilation system, but relies solely on openable windows for air exchange. Ventilation was originally provided by a natural gravity ventilation system, which distributed rising heated air via a process known as the stack effect. This system has since been abandoned (Pictures 1 and 2). Therefore, the sole source of fresh air is openable windows.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 74^{o} F to 77^{o} F, which were within the MDPH comfort guidelines of 70^{o} F to 78^{o}. As mentioned, occupants reported temperature complaints. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is also difficult to control temperature and maintain comfort without an operating mechanical ventilation system.

The relative humidity measurements in the GIS ranged from 56 to 65 percent, with three of the sixteen areas surveyed slightly above the MDPH recommended comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A few areas had water-stained ceiling tiles, which can indicate leaks from the roof or plumbing system. Occupants reported dripping pipes in the hallway. Water-damaged ceiling tiles can provide a source for mold and should be replaced after a water leak is discovered and repaired. A musty odor and water damage was noted on the windowsill in English Center A (Picture 3). These conditions can indicate a water infiltration problem with the window frame and/or window flashing.

Water-damaged materials were also observed in the basement storage area. These materials can provide a source for mold growth. The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Plants were located in several classrooms (Picture 4). Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans to prevent moistening and potential mold growth to porous building materials. A few areas had aquariums in classrooms. Aquariums should be properly maintained to prevent microbial/algae growth, which can emit unpleasant odors (Picture 5).

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 28 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 21 to 30 $\mu g/m^3$ (Table 1), which were below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Several classrooms contained dry erase boards and dry erase board markers, which may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999).

Several other conditions that can potentially affect indoor air quality were identified. Pest attractants were identified within the building. Food-based projects and re-use of food containers were observed. Proper food storage is an integral component in maintaining indoor air quality. Food should be properly stored and clearly labeled. Reuse of food containers is not recommended since food residue adhering to the surface may serve to attract pests. Occupants also reported that the GIS has had issues with cockroaches attributed to construction in a nearby building The GIS secured a private exterminator to administer an integrated pest management program of laying down bait traps every two weeks. Proteins found in the saliva and the feces of cockroaches can cause allergic reactions or the exacerbation of asthma (US EPA, 2005).

Accumulated chalk dust was noted in some classrooms. Chalk dust is a fine particulate, which can be easily aerosolized and is an eye and respiratory irritant. Missing ceiling tiles and items hanging from ceiling tiles were seen in a few areas. Missing or movement of ceiling tiles can result in the movement of dust, dirt, odors and other pollutants to occupied areas.

Boiler room odors were reported in several areas. Several pathways exist for boiler room odors and other pollutants to move from the boiler room into occupied areas. The boiler room is located in the basement of the building. The door to the stairwell leading down towards the boiler room (Pictures 6 and 7) had spaces beneath the door and light could be seen penetrating into the stairwell through this space. Another possible pathway for boiler room odors is through utility holes, such as those observed in the hallway (Picture 8). The ceiling/walls of the boiler room are penetrated by holes for utilities (e.g., electrical, plumbing). These holes can present potential pathways into occupied areas if they are not airtight. In order to explain how boiler room pollutants may be impacting adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.

- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., hot water heaters/furnace).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.

To reduce airflow between the boiler room and adjacent areas, sealing of these pollutant pathways should be considered.

GIS occupants also reported tobacco smoke odors infiltrating through the school windows from outdoors. An adult day care facility is located on the first floor of the GIS building. In order to accommodate smokers, the facility set up an outdoor smoking area. Smoke odors appear to be infiltrating through exterior windows during certain wind conditions from this designated smoking area. CEH staff detected tobacco smoke odors in classrooms above the smoking area, three stories above this designated smoking area. Second hand environmental tobacco smoke can be irritating to the eyes, nose, throat and respiratory system and should not be entering the building.

Also of note was the amount of materials stored in some classrooms. Items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Dust was also noted on fabric partitions. The partitions should be vacuumed periodically to prevent aerosolization when partitions are moved. Dust can be irritating to eyes, nose and respiratory tract.

Finally, some classrooms contained upholstered furniture and pillows (Picture 9). Upholstered furniture is covered with fabric that encounters human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent (e.g., during spring/summer), dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that if upholstered furniture were present in schools, it should be professionally cleaned on an annual basis or every six months if dusty conditions exist outdoors (IICRC, 2000).

Conclusions/Recommendations

A number of indoor air quality-related concerns were observed at the time of this assessment. To better characterize indoor air quality conditions during the heating season (e.g., exterior doors and windows closed), it is recommended that MDPH staff return to the school to conduct further testing. School officials should contact staff from the ER/IAQ Program during the fall/winter of the 2005-2006 school year to coordinate a follow-up inspection.

In view of the findings at the time of this visit, the following recommendations are made to improve general indoor air quality:

1. Use openable windows to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid freezing of pipes and potential flooding.
2. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when

the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

3. Ensure roof and/or plumbing leaks are repaired, and replace/repair water damaged building materials. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
4. Make repairs to window frames to prevent drafts and water penetration.
5. Clean and maintain aquariums to prevent mold/algal growth and associated odors.
6. Continue to use IPM methods to rid/reduce the presence of pests.
7. Consider relocating the outdoor smoking area to prevent tobacco smoke from entering the building. Consider providing alternate means for exhausting odors from the designated smoking area to prevent smoke infiltration to occupied areas. Until that time, classrooms above the outdoor smoking area should keep windows closed. All holes in the window frames need be repaired to be made airtight to prevent tobacco smoke infiltration.
8. Store and label food appropriately. Refrain from re-using food and/or containers as project materials to prevent pest attraction.
9. Ensure that the stairwell door to the boiler room is closed at all times.
10. Ensure that the stairwell door to the boiler room fits completely flush with the threshold. Seal door on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of door to provide a duel barrier. Ensure tightness of door by monitoring for light penetration and drafts around the doorframe.

11. Ensure all utility holes are properly sealed in both the boiler room and their terminus to eliminate pollutant paths of migration.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
13. Clean chalkboard/dry erase marker trays regularly to prevent the build-up of excessive chalk dust and particulates.
14. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.
15. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
16. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/indoor_air

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Picture 1

Abandoned Vent for Natural Gravity Feed Ventilation System

Picture 2

Abandoned Vent for Natural Gravity Feed Ventilation System

Picture 3

Water Damaged/Warped Windowsill in English Center A

Picture 4

Plants in Classroom

Picture 5

Aquarium in Classroom Green with Algal Growth

Picture 6

Stairwell from the Boiler Room to the First Floor

Picture 7

Boiler Room

Picture 8

Leaking pipe and open utility holes

Picture 9

Upholstered Furniture and Pillows

German School Boston **Indoor Air Results**

54 Essex St, Cambridge, MA 02139 **Table 1** **Date: 06/22/2005**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		68	78	436	ND	ND	28				
English Center A	1	77	59	734	ND	ND	25	Y # open: 3 # total: 3	N	N	Hallway DO, Inter-room DO, PF, items, plants, Comments : Water damaged window sill.
English Center B	0	77	57	711	ND	ND	23	Y # open: 3 # total: 3	N	N	Hallway DO, Inter-room DO, PF, UF, plants.
grade 5 library	0	74	61	501	ND	ND	24	Y # open: 1 # total: 5	N	N	CD, UF, aqua/terra, dust, plants.
women's restroom	0	75	60	504	ND	ND	23	N # open: 0 # total: 0		Y ceiling dust/debris	
394 A	0	77	56	528	ND	ND	22	Y # open: 0 # total: 3	N	N	Hallway DO, #MT/AT : 1, CD, DEM, UF, plants.
394 B	0	77	56	536	ND	ND	22	Y # open: 3 # total: 5	N	N	Inter-room DO,

ppm = parts per million
μg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
staff room	3	76	62	739	ND	ND	22	Y # open: 3 # total: 8	N	N	CD, PC, PF.
314 B	10	75	65	1050	ND	ND	30	Y # open: 3 # total: 6	N	N	Hallway DO, #WD-CT : 1, UF.
girls restroom	0	75	59	628	ND	ND	22	N # open: 0 # total: 0	N	Y wall dust/debris	Inter-room DO,
boys restroom	0	74	58	489	ND	ND	23	Y # open: 1 # total: 3	N	Y wall	Hallway DO, Inter-room DO,
men's restroom	0	75	59	510	ND	ND	23	N	N	Y ceiling	Comments : scented candles.
192 B	0	76	58	570	ND	ND	24	Y # open: 2 # total: 6	N	N	Hallway DO, CD, items, dust, FC re-use, plants.
172 A	11	75	59	684	ND	ND	27	Y # open: 1 # total: 10	N	N	Hallway DO, CD, UF, FC re-use, plants.

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									Supply	Exhaust	
pre K	14	75	59	484	ND	ND	22	Y # open: 2 # total: 10	N	N	Hallway DO, UF, items hanging from CT, plants.
principal	2	75	60	552	ND	ND	22	Y # open: 1 # total: 3	N	N	window-mounted AC, plants.
entry level	0	76	58	502	ND	ND	21	Y # open: 1 # total: 6	N	N	Hallway DO, UF, dust, plants.

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